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Design of Multiband Antenna Using Fractal and DGS Techniques

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ABSTRACT- A minkowski fractal antenna is designed with a dimensions of substrate (27x27x1.6)mm3, patch of dimensions (27x27)mm2 and ground plane of dimensions (40x40)mm2 has been proposed with improved impedance bandwidth and gains for wireless communication applications.In this work, totally four types of antennas were designed and mentioned. Four types of antennas mean one is minkowski fractal antenna made by using microstrip patch and works at three different set of frequencies (8.17GHz, 9.20GHz & 15.32GHz) with high gain which mainly covers the applications of microwave frequency X-band and Ku band. Secondly, the combination of fractal and DGS that works at 11.5 GHz, which covers the applications of Ku band. The third design is DGS and works at dual set of frequencies (2.4 GHz & 5.25 GHz) and which mostly covers the major applications of WLAN, S-band frequency. Finally, the fourth design is plus shaped DGS works at multiple set of frequencies (13.73GHz ,15.50GHz,18.18GHz,21.04GHz) which mainly covers the major applications of K-band and Ku-band frequencies.

KEYWORDS- Defected Ground Structure, frequency, gain, minkowski fractal antenna.

I. INTRODUCTION

Today, in the world,we need small, multiple resonant frequencies antennas.These challenges have been somewhat achieved by researchers[1,2]·For miniaturization, various methods have been proposed like sierpenski[3] , fractal[4].An H-fractal multiband antenna is designed for a variety of antenna applications[5].An emerging technique to improve the performance of a microstrip patch antenna is by introducing defected ground structure (DGS)[6,7].In Dawit Fistum[8], proximity coupled feed rectangular microstrip patch antenna using a new Defected Ground Structure is designed with improved antenna parameters with returnloss of -47.9dB and resonates in S-band at frequency 2.4 GHz.In Esa,the experimental investigations have been carried out on a microstrip antenna that has been embedded with a DGS element having V-slot shape. It was observed that the undesired cross-polarisation has been reduced and the impedance bandwidth has widened [9].

II. MATHEMATICAL ANALYSIS

Width(W):

$$W = \frac{C_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Where,
W= Width of the patch
Co= Speed of light
ε_r = value of the dielectric substrate
Effective refractive index:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}, {}^{W}/_{h} > 1$$

Length(L):

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Where h= height of the substrate

$$L = \frac{C_0}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

Length(Lg) and Width(Wg) of ground plane:
Lg=6h+L
Wg=6h+W

III. SIMULATION AND RESULTS

A. Minkowski fractal antenna

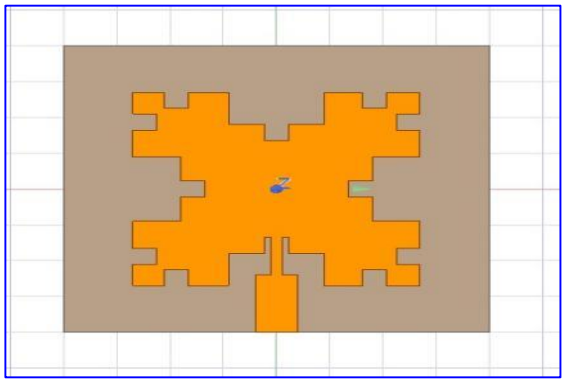

Figure 1: Front view of antenna

Fig 1 shows front view of minkowski fractal antenna i.e,it is the patch of the antenna.The substrate is designed with the dimensions (27x27x1.6)mm^3 and patch with dimensions (27x27)mm^2.

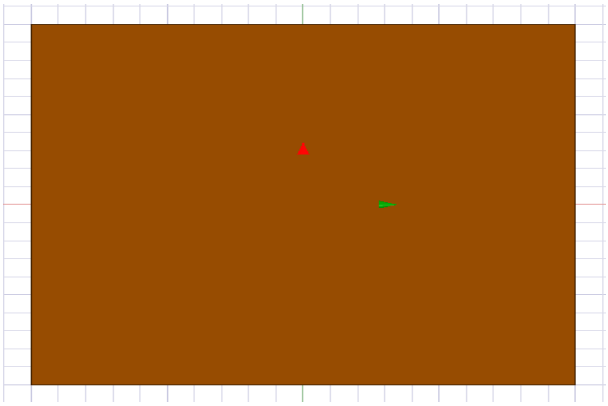

Figure 2: Back view of antenna

Fig 2 shows back view of minlowski fractal antenna i.e,it is ground plane of the antenna.The ground plane is designed with dimensions (40x40)mm^2.

B. Returnloss Plot

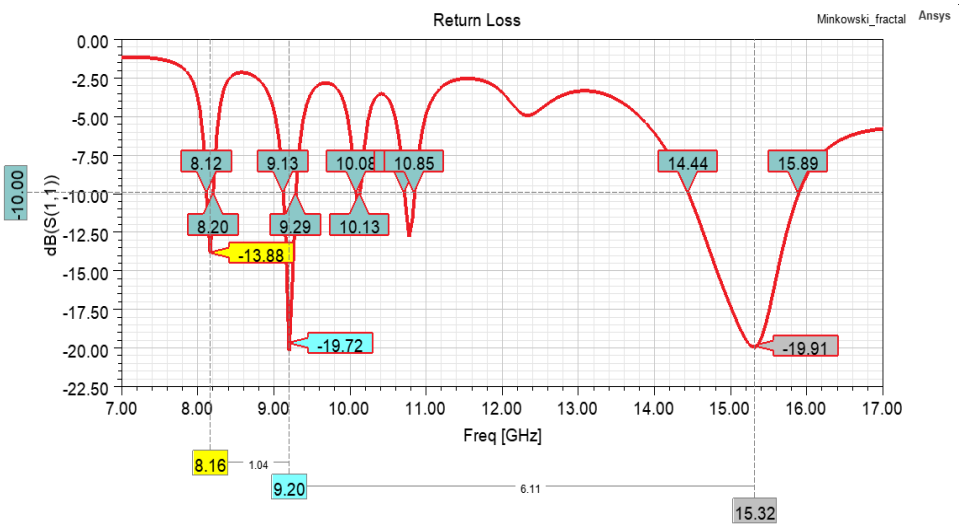

Figure 3: Returnloss plot antenna

From fig 3 it is observed that the return loss obtained as -13.88dB,-19.72dB,-19.91dB at 8.16GHz,9.20GHz,15.32GHz frequencies respectively.The antenna resonates at frequencies 8.12 GHz,8.20 GHz,9.13 GHz,9.29 GHz,10.08 GHz,10.13

GHz,10.45 GHz which is used in multi band applications.Again the antenna resonates at 14.44 GHz and 15.89 GHz frequencies which is used in single band applications.

C. *Vswr* Plot

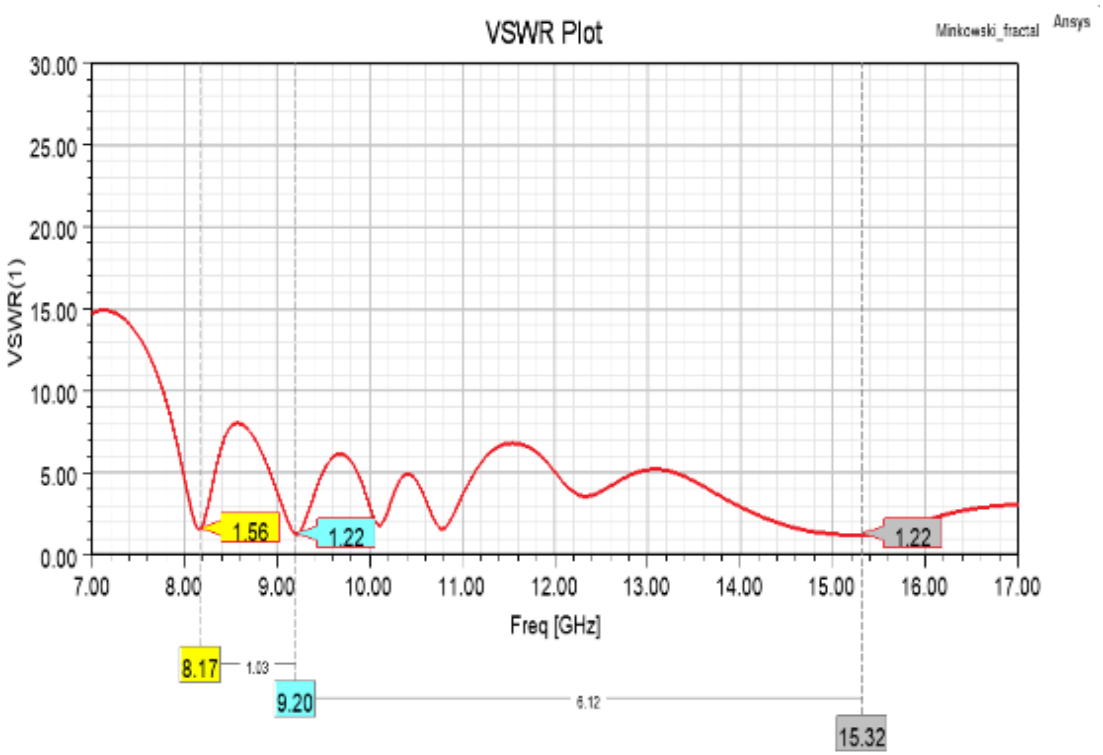

Figure 4: VSWR plot of antenna

Fig 4 shows the VSWR plot of minkowski fractal antenna.The values are obtained as 1.56 at 8.17GHz frequency,1.22 at 9.20GHz frequency and 1.22 at 15.32GHz frequency.

D. Gain Plots

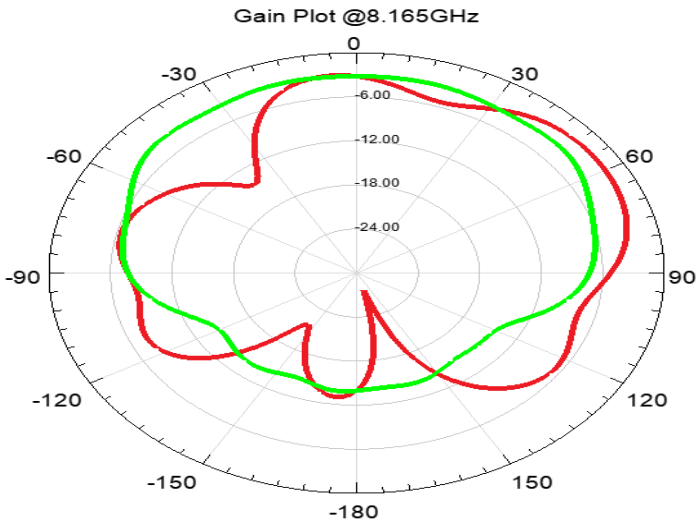

Figure 5: 2D gain plot at 8.16GHz

Fig 5 shows the 2D gain plot of minkowski fractal antenna at 8.16 GHz frequency.This plot is generated at working frequency of antenna.

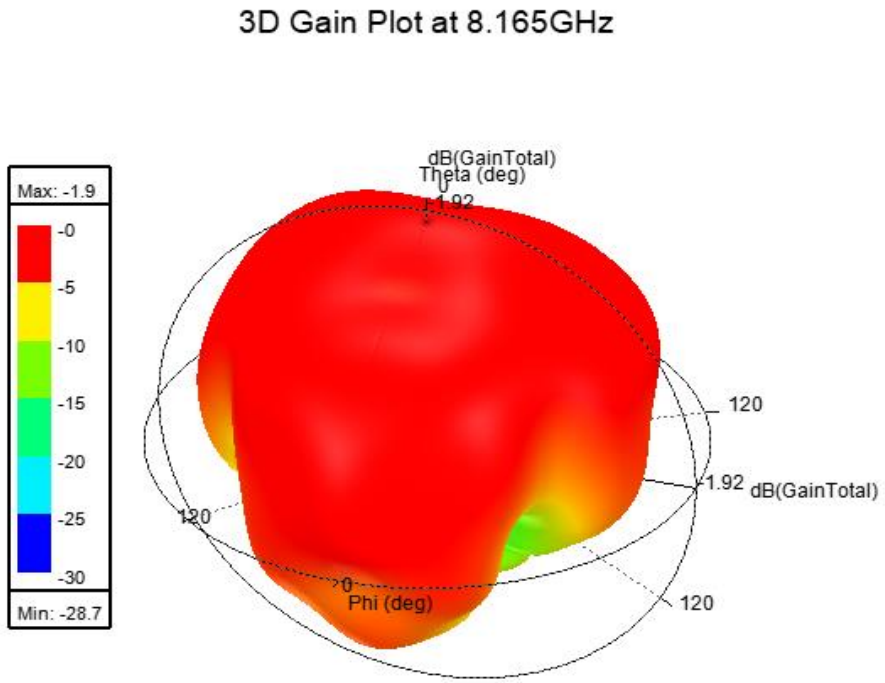

Figure 6: 3D gain plot at 8.16 GHz

Fig 6 shows 3D gain plots of minkowski fractal antenna obtained at 8.16 GHz frequency.The maximum gain obtained is -1.9dB.The minimum gain obtained is -28.7 dB.

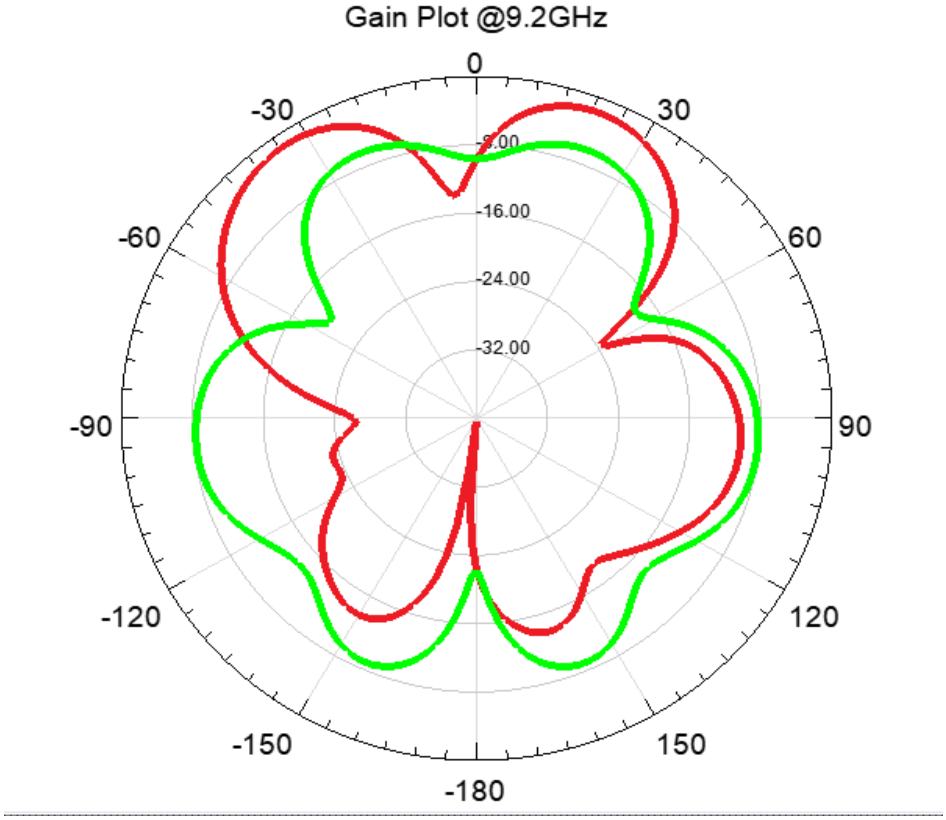

Figure 7: 2D gain plot at 9.2 GHz

Fig 7 shows the 2D gain plot of minkowski fractal antenna generated at 9.2 GHz frequency.

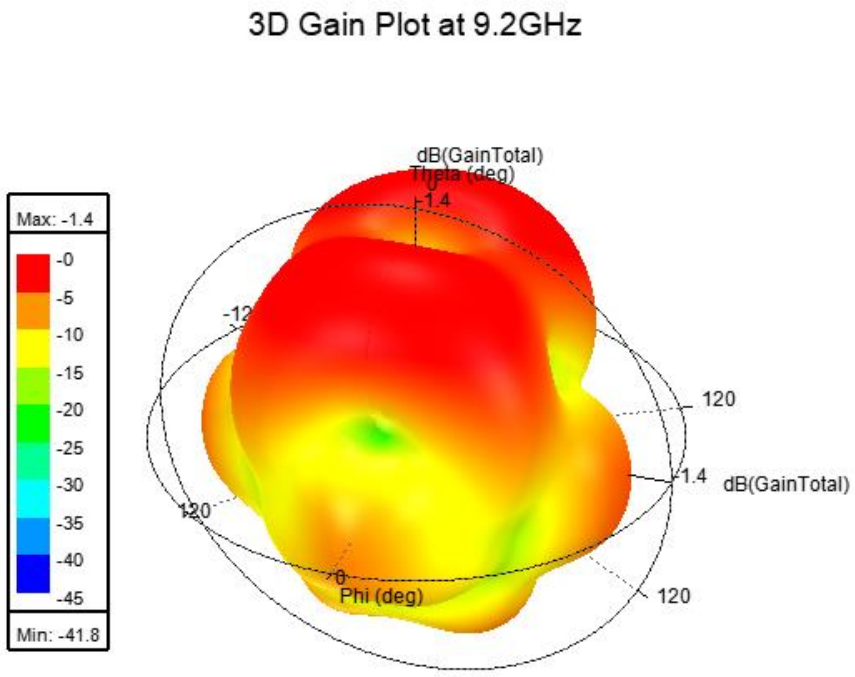

Figure 8: 3D gain plot at 9.2 GHz

Fig 8 shows 3D gain plot of minkowski fractal antenna at 9.12GHz frequency.The maximum gain obtained is -1.4dB.The minimum gain obtained is -45 dB.

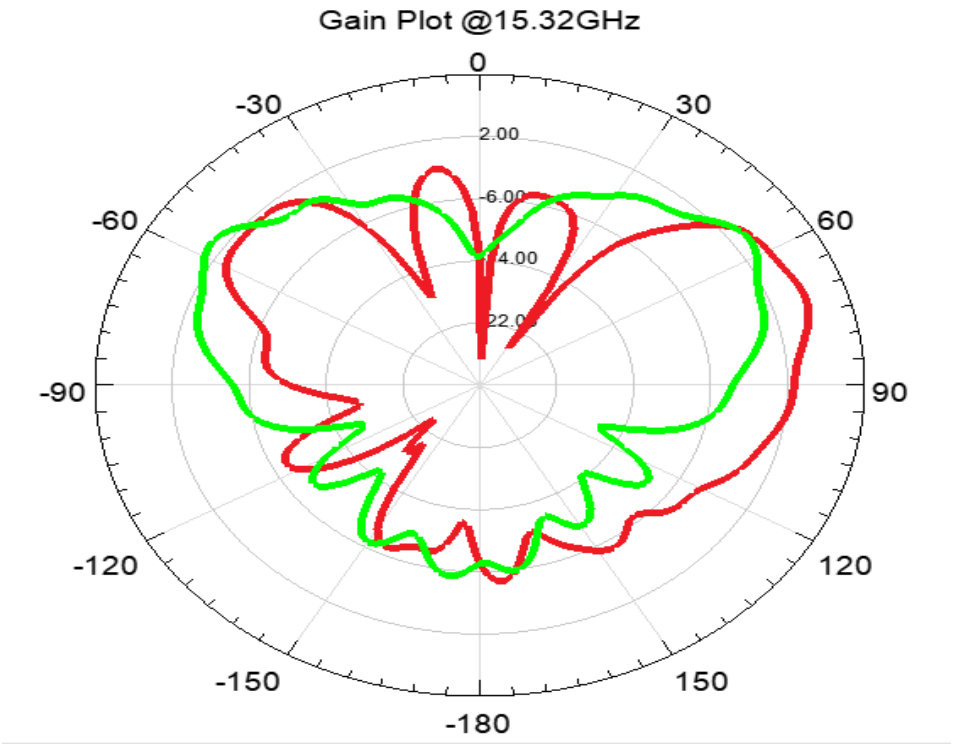

Figure 9: 2D plot at 15.32 GHz

Fig 9 shows the 2D gain plot of minkowski fractal antenna generated at 15.32 GHz frequency.

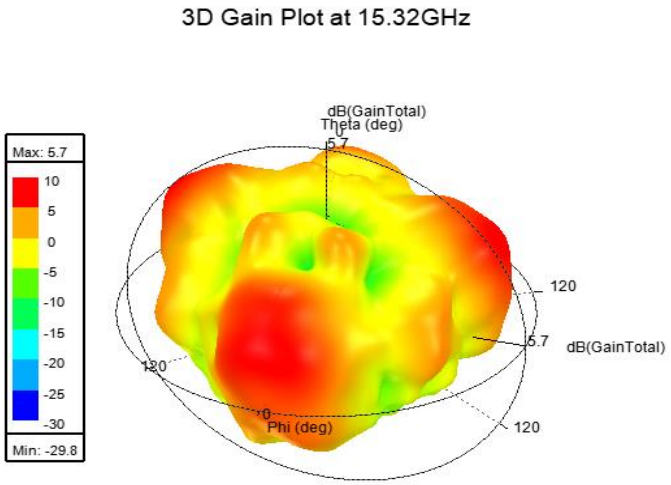

Figure 10: 3D plot at 15.32 GHz

Fig 10 shows 3D gain plot of minkowski fractal antenna at 15.32 GHz frequency. The maximum gain obtained is 5.7 at 15.32 GHz frequency. The minimum gain obtained is -29.8 dB.

IV. Combination of fractal and DGS

A. Proposed Antenna

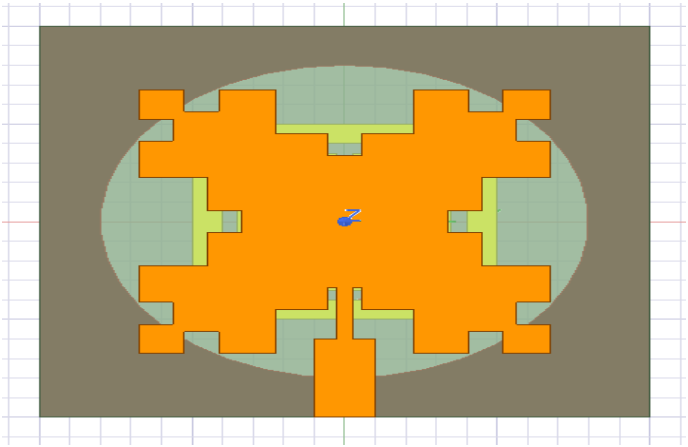

Figure 11: Front view of antenna

Fig 11 shows front view of fractal using DGS.

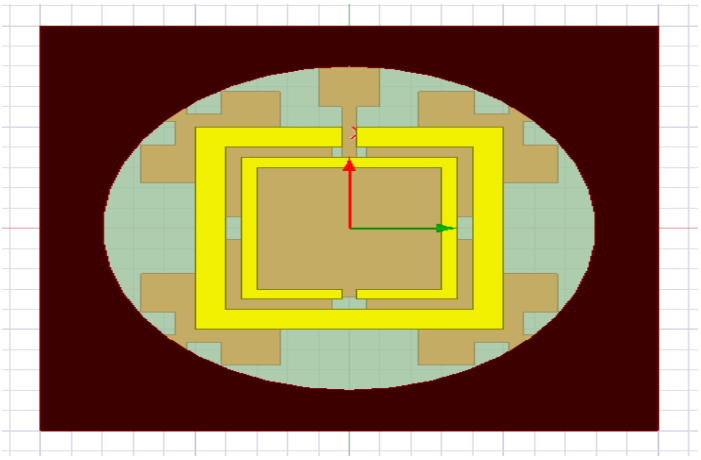

Figure 12: Back view of antenna

Fig 12 shows ground plane of fractal using DGS.

B. Returnloss Plot

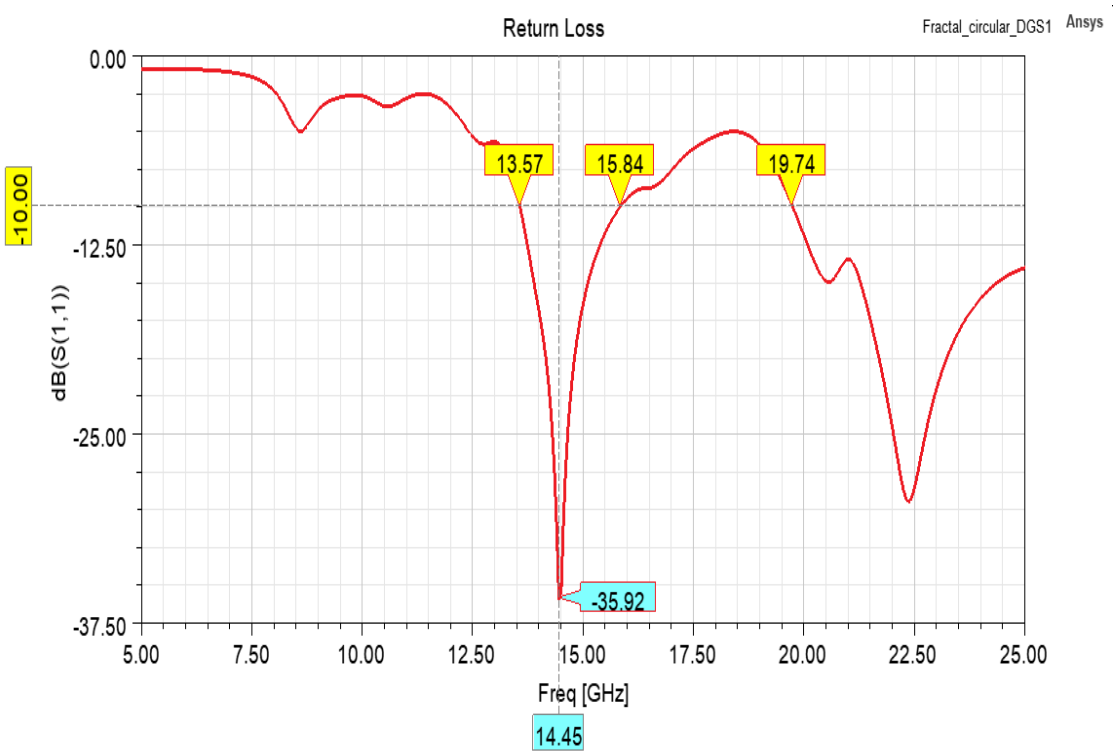

Figure 13: Returnloss plot of antenna

For combination of fractal and DGS the returnloss of -35.92dB is obtained at 14.45GHz frequency. The antenna resonates at 13.57 GHz,15.84 GHz and 19.74 GHz frequencies.

C. Vswr Plot

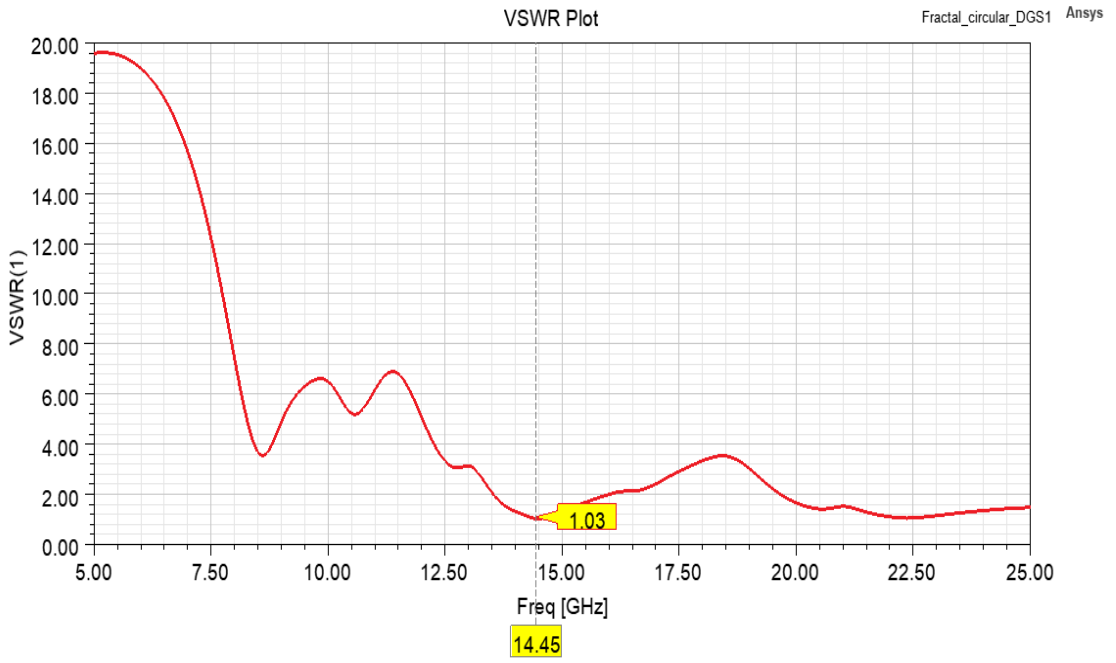

Figure 14: VSWR plot of antenna

Fig 14 shows VSWR plot of fractal using DGS.The VSWR value obtained for combination of fractal and DGS is 1.03 at 14.45GHz frequency.

D. Gain Plots

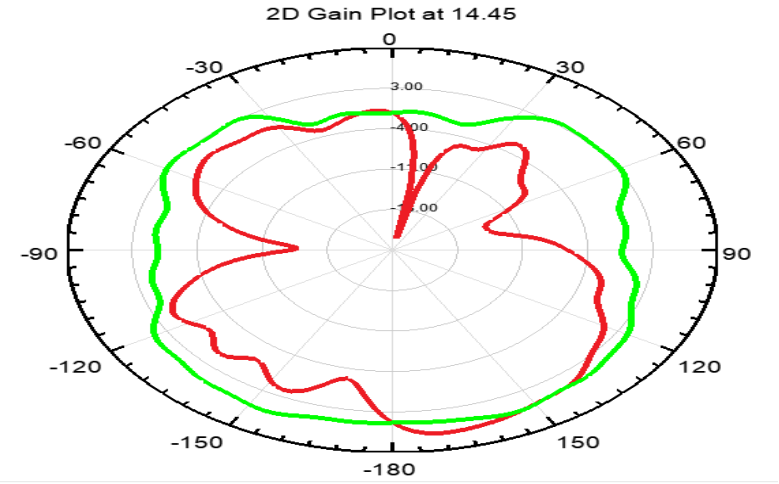

Figure 15: 2D gain plot at 14.45 GHz

Fig 15 shows the 2D plot of antenna which is generated at 14.45 GHz frequency(working frequency).

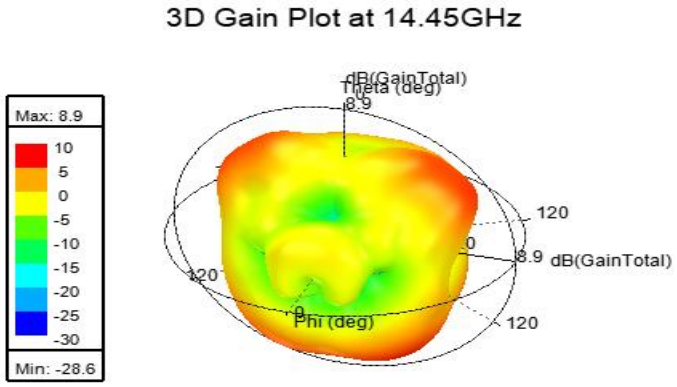

Figure 16: 3D plot at 14.45 GHz

Fig 16 shows the 3D gain plot of antenna. The maximum gain obtained for combination of fractal and DGS antenna is 8.9dB at 14.45 GHz frequency. The minimum gain obtained is -30 dB.

V. DEFECTED GROUND STRUCTURE (DGS)

A. Figure

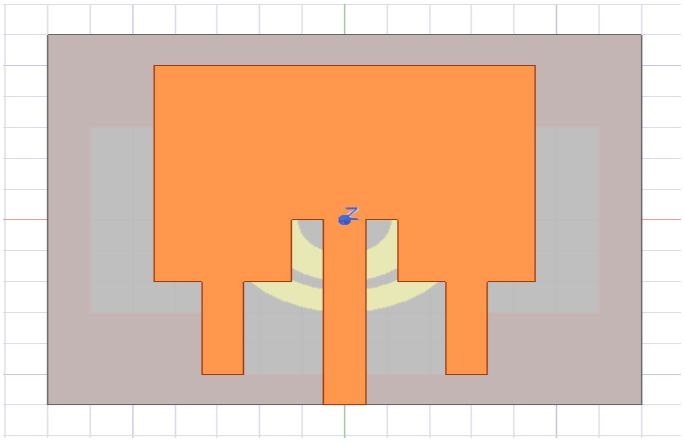

Figure 17: Front view of antenna

Fig 17 shows patch of the DGS.

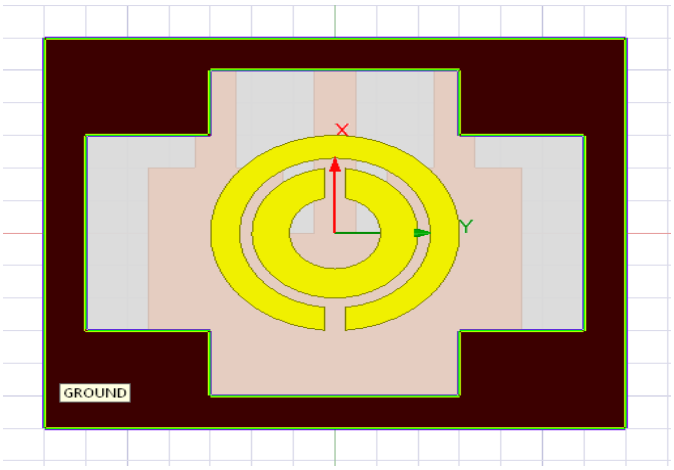

Figure 18: Back view of antenna

Fig 18 shows ground plane of DGS.

B. Returnloss Plot

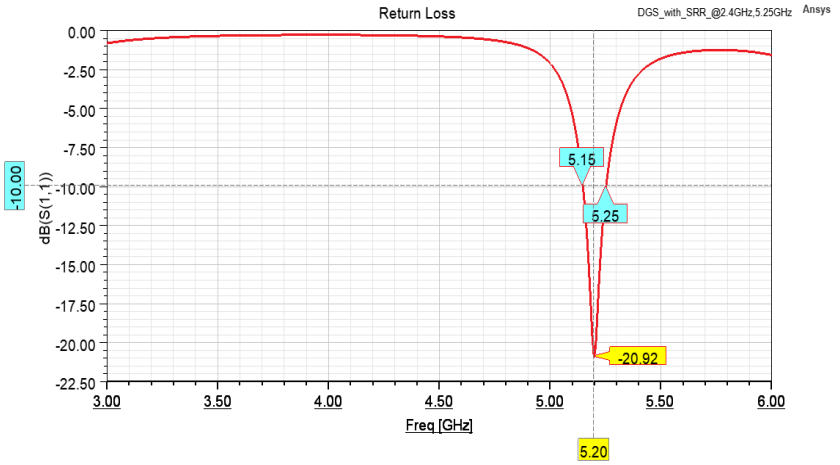

Figure 19: Returnloss plot of antenna

Fig 19 shows returnloss plot of DGS. The returnloss obtained for DGS is -20.92dB at 5.2GHz frequency.The antenna resonates at 5.15 GHz and 5.25 GHz frequencies.

C. Vswr Plot

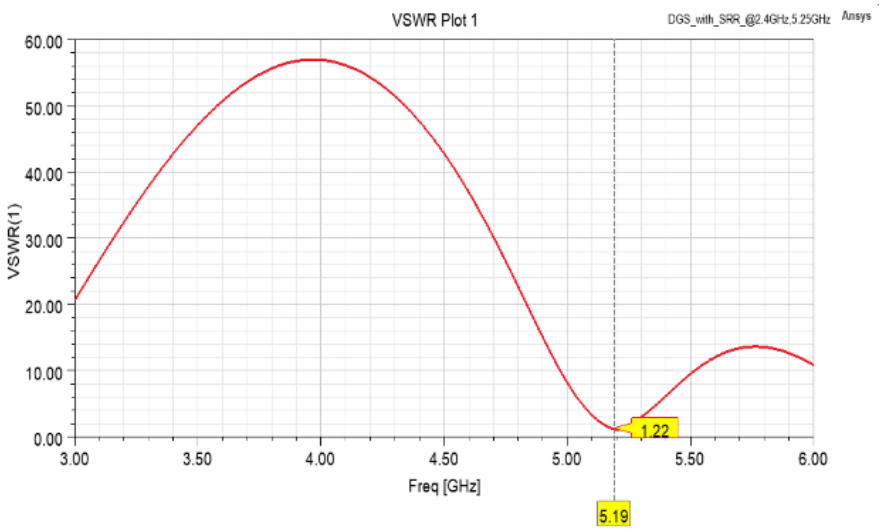

Figure 20: VSWR plot of antenna

Fig 20 shows the VSWR plot of DGS.The readings obtained as 1.22 at 5.2GHz frequency.

D. Gain Plots

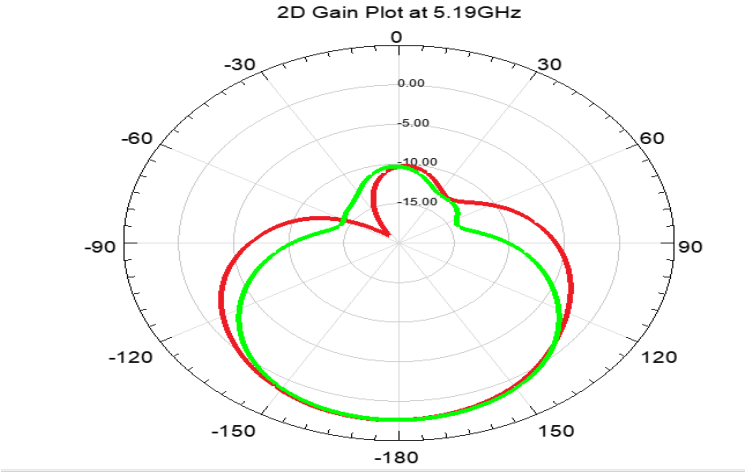

Figure 21: 2D gain plot at 5.19 GHz

Fig 21 shows 2D gain plot of DGS which is generated at 5.19 GHz frequency.

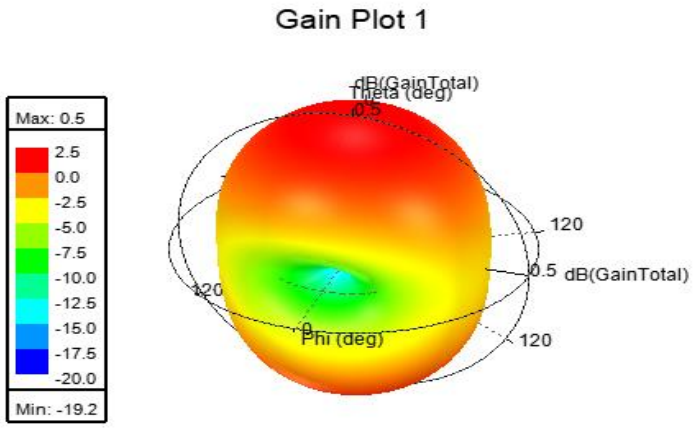

Figure 22: 3D plot of at 5.19 GHz

Fig 22 shows 3D gain plot of DGS. The maximum gain obtained for DGS is 0.5dB at 5.19 GHz frequency. The minimum gain obtained is -19.2 dB.

VI. PLUS SHAPED DGS

A. Figure

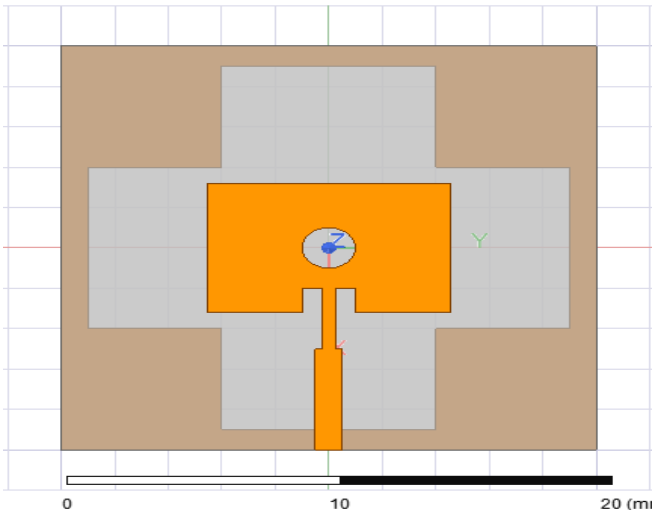

Figure 23: Front view of antenna

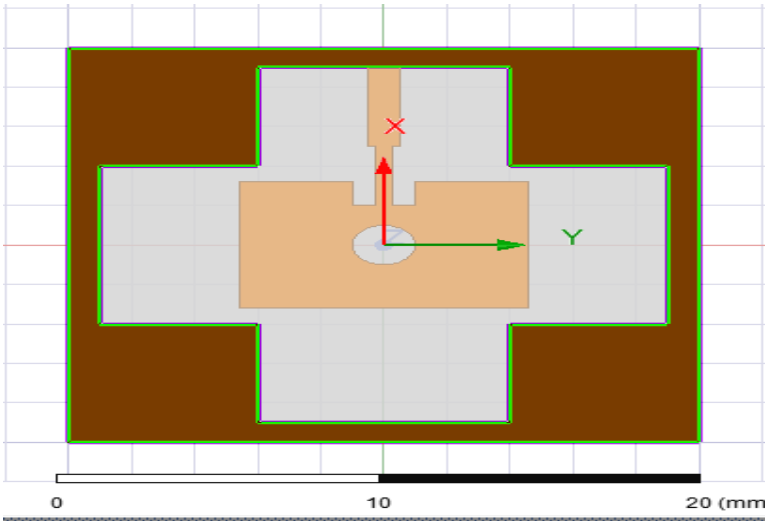

Figure 24: Back view of antenna

B. Returnloss Plot

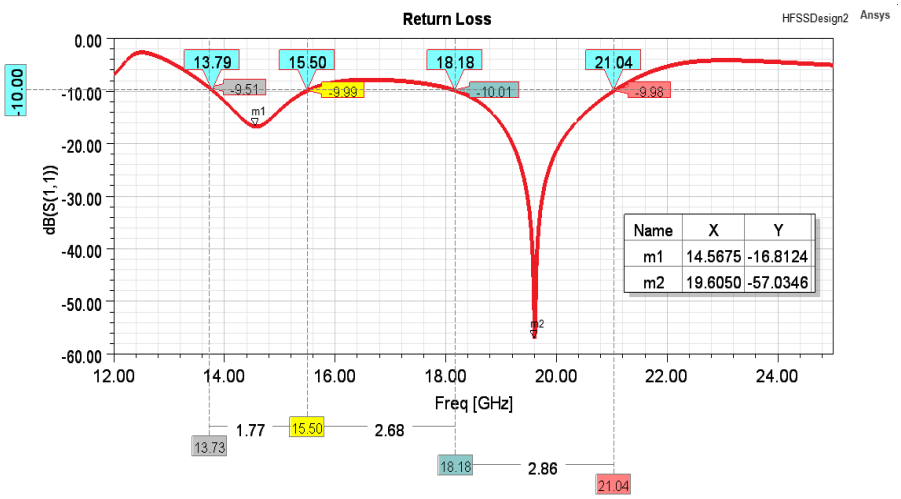

Figure 25: Returnloss plot of antenna

Fig 25 shows the return loss plot of plus shaped DGS. The return loss obtained is -16.8 dB,-57dB at 14.56GHz,19.6GHz frequencies respectively. The antenna resonates at 13.79 GHz,15.50 GHz18.18 GHz,21.04 GHz frequencies.

B. Vswr Plot

Figure 26: VSWR plot of antenna

Fig 26 shows VSWR plot of plus shaped DGS. The readings obtained is 1.02 at 19.6 GHz frequency.

C. Gain Plots

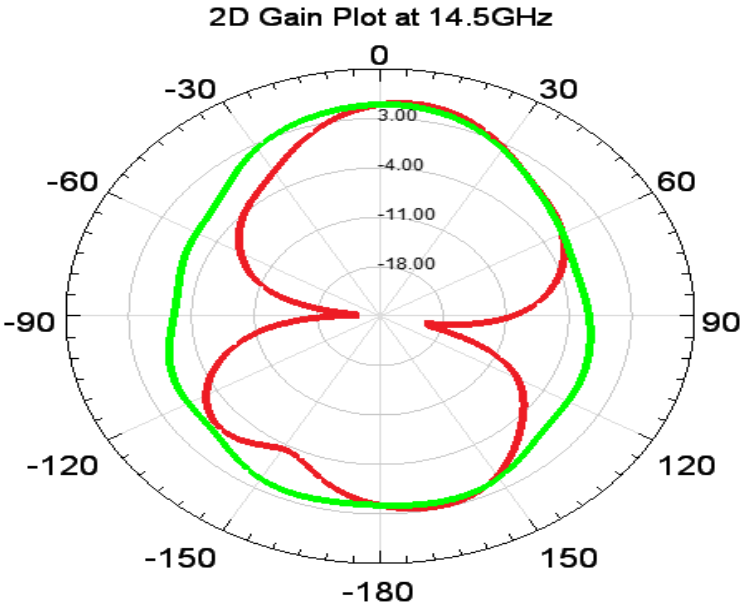

Figure 27: 2D gain plot at 14.5 GHz

Fig 27 shows 2D gain plot of plus shaped DGS which is generated at 14.5 GHz frequency.

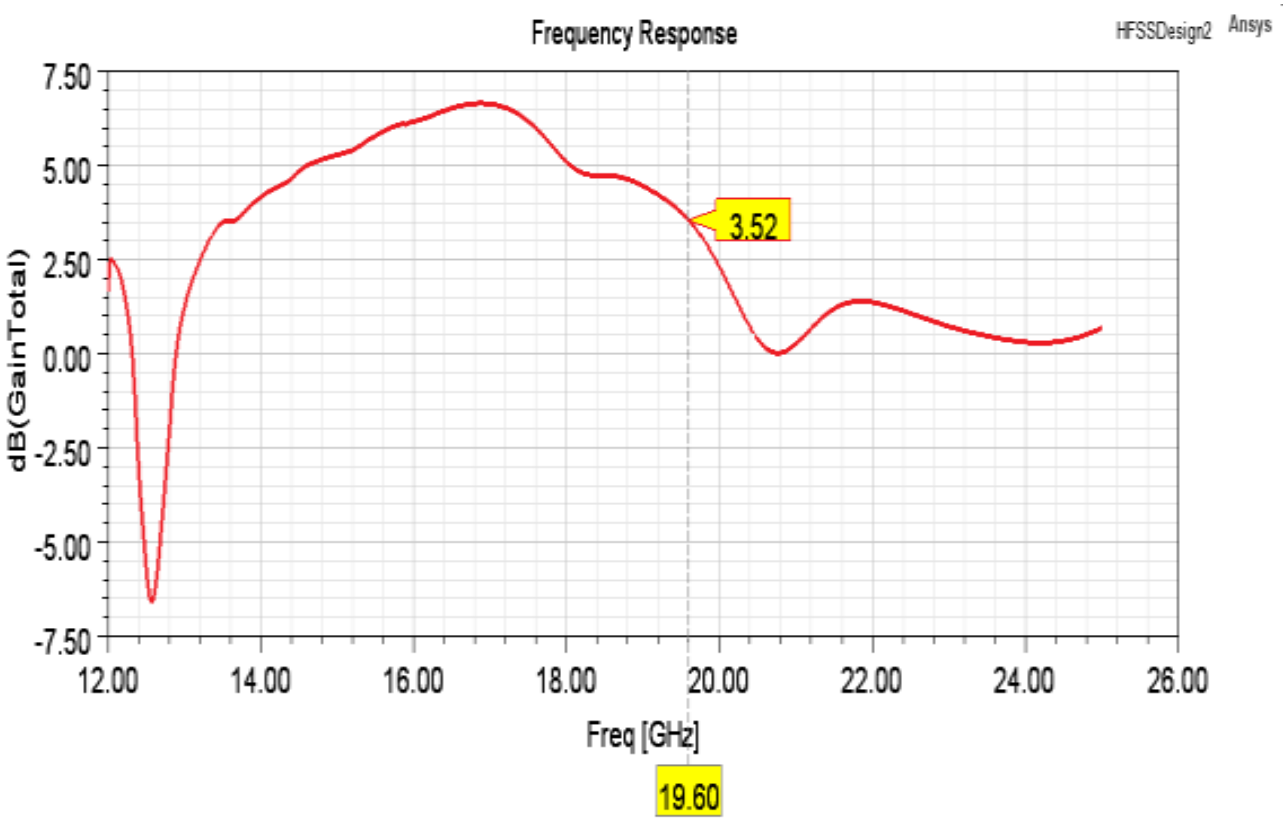

Figure 28: 3D plot at 14.45 GHz

Fig 28 shows 3D gain plot of lus shaped DGS which is generated at 14.45 GHz frequency. The maximum gain obtained for plus shaped DGS is 5.3dB at 14.45 GHz frequency. The minimum gain obtained is -22.6 dB.

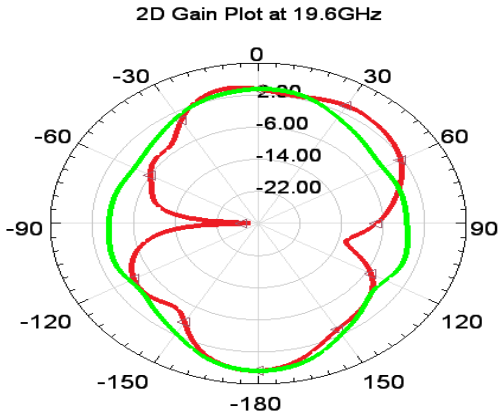

Figure 29: 2D plot at 19.6 GHz

Fig 29 shows 2D gain plot of plus shaped DGS which is generated at 19.6 GHz frequency.

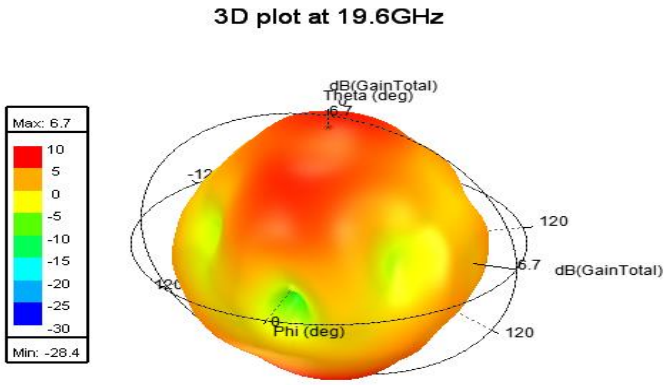

Figure 30: 3D plot at 19.6 GHz

Fig 30 shows 3D gain plot of plus shaped DGS which is generated at 19.6 GHz frequency. The maximum gain

FREQUENCY RESPONSE

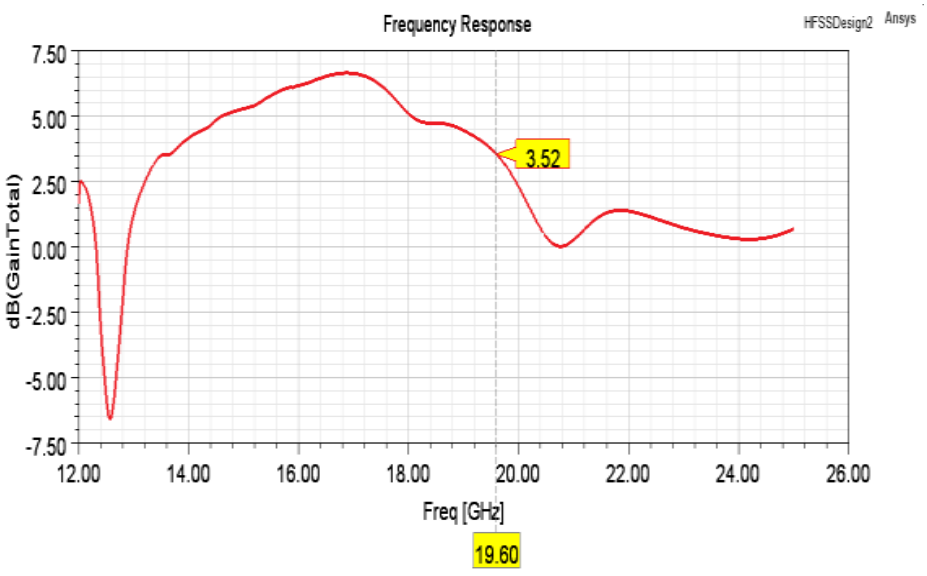

Figure 31: Frequency response of antenna

Fig 31 shows frequency response of antenna at 19.6 GHz frequency.The gain obtained is 3.52 dB.

Table 1: Comparison of all the designed antennas

ANTENNA PARAMETER	MINKOWSKI FRACTAL ANTENNA	FRACTAL USING DGS	DEFECTED GROUND STRUCTURE(DGS)	PLUS SHAPED DGS
Nature	Multi-band	Single band	Single band	Dual band
Resonating Frequency	8.16GHz 9.2GHz 15.32GHz	14.45 GHz	5.2GHz	14.56 GHz 19.6 GHz
Operating range	8.12 - 8.20GHz 9.13 - 9.29GHz 14.44 - 15.89GHz	13.57 - 15.84GHz	5.15 - 5.25GHz	13.79 - 15.5GHz 18.18 - 21.04GHz
Return loss	-13.88dB at 8.16GHz -19.72dB at 9.2GHz -19.91dB at 15.32GHz	-35.92dB at 14.45GHz	-20.92dB at 5.2GHz	-16.8dB at 14.56GHz -57 dB at 19.6GHz
VSWR	1.56 at 8.16GHz 1.22 at 9.2GHz 1.22 at 15.32GHz	1.03 at 14.45GHz	1.22 at 5.2GHz	1.3 at 14.56GHz 1.03 at 19.6GHz
Band width	80MHz 150MHz 1.45GHz	2.27GHz	100MHz	1.71GHz 2.86GHz
Applications	X band, Ku band	Ku band	C band	Ku band, K band

Minkowski fractal antenna is designed with a dimensions of substrate (27x27x1.6) mm3 and patch of dimensions (27x27)mm2 and ground plane of dimensions (40x40)mm2..The return loss obtained as -13.88dB,-19.72dB,-19.91dB at 8.16GHz,9.20GHz,15.32GHz frequencies respectively..The VSWR values are as 1.56 at 8.17GHz frequency,1.22 at 9.20GHz frequency and 1.22 at 15.32GHz frequency. The antenna resonates at 8.12GHz,8.20GHz,9.13GHz,9.29GHz,10.1GHz,10.72GHz, 10.85GHz,14.44GHz,15.89GHz frequencies. Combination of fractal and DGS is designed with dimensions patch (27*27)mm3 and with cuts 3mm.The return loss of -35.92dB is obtained at 14.45GHz frequency. The VSWR is of 1.03 at 14.45GHz frequency. Defected ground structure(DGS) antenna is designed rings in the patch. The return loss of -20.92dB at 5.2GHz frequency. The VSWR readings obtained as 1.22 at 5.2GHz. Plus shaped DGS is designed which works in the applications of Ku band and K band. The return loss obtained is -16.8 dB,-57dB at 14.56GHz,19.6GHz frequencies respectively. The VSWR is 1 at 19.60GHz frequency.

VII. CONCLUSION

The proposed antennas are designed using HFSS 2021 R2 simulator which is used for simulating the characteristics. The simulated result shows dual band operation in X-band and Ku-band for fractal antenna with enhanced bandwidth of 80MHz, 150MHz and 1.4GHz, which can be used for Short Range Tracking, Missile guidance, High resolution Mapping and Satellite altimetry. The simulated results for DGS represent the enhanced performance of the proposed antenna. The simulated result shows dual band operation in C-band and K-band with enhanced bandwidth of 100MHz and 2.86GHz, which can be used for Long Range Tracking, Weather observation, Satellite communication and Police Radar.

ABBREVIATIONS

DGS(Distorted Ground Structure),HFSS(High Frequency Software Simulation),WLAN(Wireless Network)

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